GLOBAL AND REGIONAL RESOLUTION STUDIES OF MAGELLAN GRAVITY DATA: IMPLICATIONS FOR INFERRING LITHOSPHERIC THICKNESS

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SUMMARY

Establishing temporal and spatial variations in lithospheric thickness on Venus is crucial to our understanding of the thermal and tectonic history of the planet. Magellan gravity and topography data, combined with a flexural model of compensation, in theory allow us to estimate lithospheric thickness globally, constraining the present day thermal boundary layer thickness: however, we are hindered by the varying spatial resolution of the gravity data, which places a lower bound on our estimates of lithospheric thickness and controls whether we can distinguish between dynamic and static compensation mechanisms. We present global and regional analyses of the maximum resolution available from Cycle 5 and Cycle 6 Magellan gravity data, and we discuss the implications of our results for estimating lithospheric thickness. The availability of the complete Cycle 5 and 6 gravity data allows the extension of earlier, spatially limited, resolution studies [1,2] using line-of-site (LOS) Doppler velocity residuals and a multi-taper spectral estimation technique [3]. The effects of spacecraft altitude, viewing geometry and noise on the resolution in the data are investigated globally. For specific regions we compare our estimates of the maximum resolution in the data with estimates of the spatially localized maximum spectral resolution l_{Nyq} [4], available from current spherical harmonic models [5]. l_{Nyq} is always less than the maximum spherical harmonic degree of the field l_{obs}, when analyzing a spatially restricted region, as is typically done in geophysical studies [*e.g.*, 4]. The maximum resolution in the gravity data occurs over Bell Regio. Our results from Bell and other regions indicate the need for higher resolution spherical harmonic models, in order to describe fully the signal available from Magellan gravity data.

METHOD

We obtain grids of the minimum resolvable wavelengths in the gravity data from four subsets of the data: (a) Cycle 5 descending (periapsis-side) tracks, (b) Cycle 5 ascending (apoapsis-side) tracks, (c) Cycle 6 descending tracks, and (d) Cycle 6 ascending tracks. This subdivision of the data is necessary, as our approach is based on the track-to-track spectral coherence of the LOS Doppler velocity residuals and requires closely-spaced, nearly-parallel tracks. High latitudes are excluded from our analyses due to crossing tracks. The LOS residuals for Cycles 5 and 6 are given with respect to a degree and order 40 spherical harmonic model (MGN40E); thus most of the power at wavelengths longer than approximately 1000 km has been removed from the residuals. For each subset of the data the resolution grid is computed as follows:

(1) Gaps in the LOS data are filled by interpolation, and the data are first-differenced along-track to ensure the removal of long wavelength trends.

(2) The track-to-track coherence is calculated. Multi-taper spectral estimates of the power, coherence, and phase are computed between adjacent pairs of orbits using a sliding window, typically of length 20°–30° in latitude. Multi-taper spectral estimation is necessary because of the short time series; a 30° arc of an orbit contains about 250 points. A trade-off between spectral resolution and spectral variance occurs, dependent on the number of multi-tapers used.

(3) Spectra are then averaged across-track using a sliding window to obtain smooth spectral estimates. Preliminary results suggest that averaging over a 15° longitude band is sufficient to obtain smooth spectra. Trade-offs between spatial and spectral resolution / variance result from the choice of window size along-track and

across-track. A robust average and the 1-σ uncertainties in the mean are computed for the coherence and phase spectra.

(4) The value of the coherence which characterizes the noise spectrum is used as the cut-off for establishing the shortest wavelength signal resolvable in the data. The average upper 1-σ level on the coherence estimate is computed for the noise spectrum (wavelengths shorter than 150 km). In general this level corresponds to a coherence in the range 0.25 – 0.4. Thus this method provides a consistent statistical description of the signal-to-noise level used to establish the minimum resolvable wavelength λ_c in the LOS data.

(5) The mean λ_c along with the 1-σ errors in λ_c are calculated.

RESULTS

Preliminary results for six illustrative regions using two subsets of the LOS dataset are shown in Table 1. Initially we focussed on Cycle 5 periapsis-side data (due to good viewing geometry and low spacecraft altitudes) and Cycle 6 apoapsis-side data (good spatial coverage, and orbit more nearly circular than in Cycle 5). Table 1 shows the mean resolution (l_{ave}) for each area, given in terms of maximum resolvable spherical harmonic degree, along with the upper 1-σ error bound (l_{upper}). Also given is an estimate of the local Nyquist spherical harmonic degree, l_{Nyq}, an alternative estimate of resolution in the data based on a comparison of the localized power and error spectra [4] for the degree and order 120 spherical harmonic model [5]. l_{Nyq} is the maximum degree to which localized estimates of the gravity / topography admittance spectrum should be intepreted. It is evident that there is good agreement between l_{Nyq} and l_{ave} in these regions. Because of the choice of localization currently used to compute l_{Nyq}, our estimates of l_{Nyq} and l_{ave} for a given region do not correspond to exactly the same spatial windows; this issue will be addressed in further analyses and our results also extended to include Cycle 5 apopasis-side and Cycle 6 periapsis-side data.

Table 1

Region	l_{ave}	l_{upper}	l_{Nyq}
Bell	84	127	>80
W. Eistla	69	100	74
Thetis	63	95	61
Niobe	54	91	60
Themis	51	76	59
Alpha	45	71	50

It is clear that the best resolution in the gravity data occurs over Bell Regio, where our current estimate of the upper 67% confidence limit yields a maximum resolvable spherical harmonic degree greater than 120. Gravity / topography admittance studies [4,6] show a clear transition at Bell Regio from dynamic to elastic support of topography; our estimates of the resolution in the gravity data indicate that the interpretation of elastic thicknesses in the range 20–30 km is reasonable. In contrast, inferences of elastic thickness in regions such as Themis are made more difficult by the intrinsic lower resolution of the gravity data.

Our results indicate that higher spherical harmonic degree models are necessary to describe adequately the Magellan gravity data. We note that the increase in power at the highest spherical harmonic degrees, even for the current degree 120 model ($\lambda \geq$320 km), indicates that there are regions in which there is information in the gravity data at wavelengths less than 320 km. To ensure an adequate number of degrees of freedom in the regularized inversions, any final global field model should have a maximum spherical harmonic degree corresponding to wavelengths shorter than the minimum resolvable wavelength in the data (*i.e.*, greater than l=127). A new spherical harmonic field model to degree and order 180 is justified by the LOS data and would permit the interpretation of localized spectra out to the maximum resolution inherent to the dataset.

References: [1] C. L. Johnson & D. T. Sandwell, *LPSC XXVI*, 681-682, 1995; [2] C. L. Johnson, *PhD. Thesis*, 1994; [3] D. J. Thomson, *Proc. IEEE, 70*, 1055-1096, 1982; [4] M. Simons *et al.*, *GJI*, submitted, 1996; [5] A. S. Konopliv & W. L. Sjogren, in *Venus II*, in press, 1996; [6] S. E. Smrekar, *Icarus*, *112*, 2-26, 1994